

2013

2015

2020

2025

2030

2035

2040

2045

2050



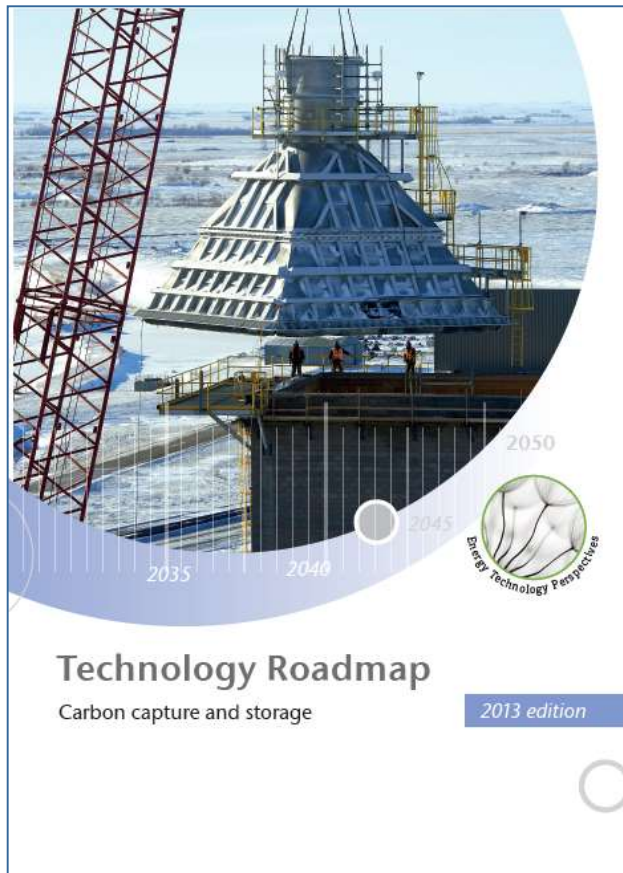
## IEA CCS Roadmap – and what's next?

# Outline

- CCS Roadmap key points and actions
- Further developments
- What's next?



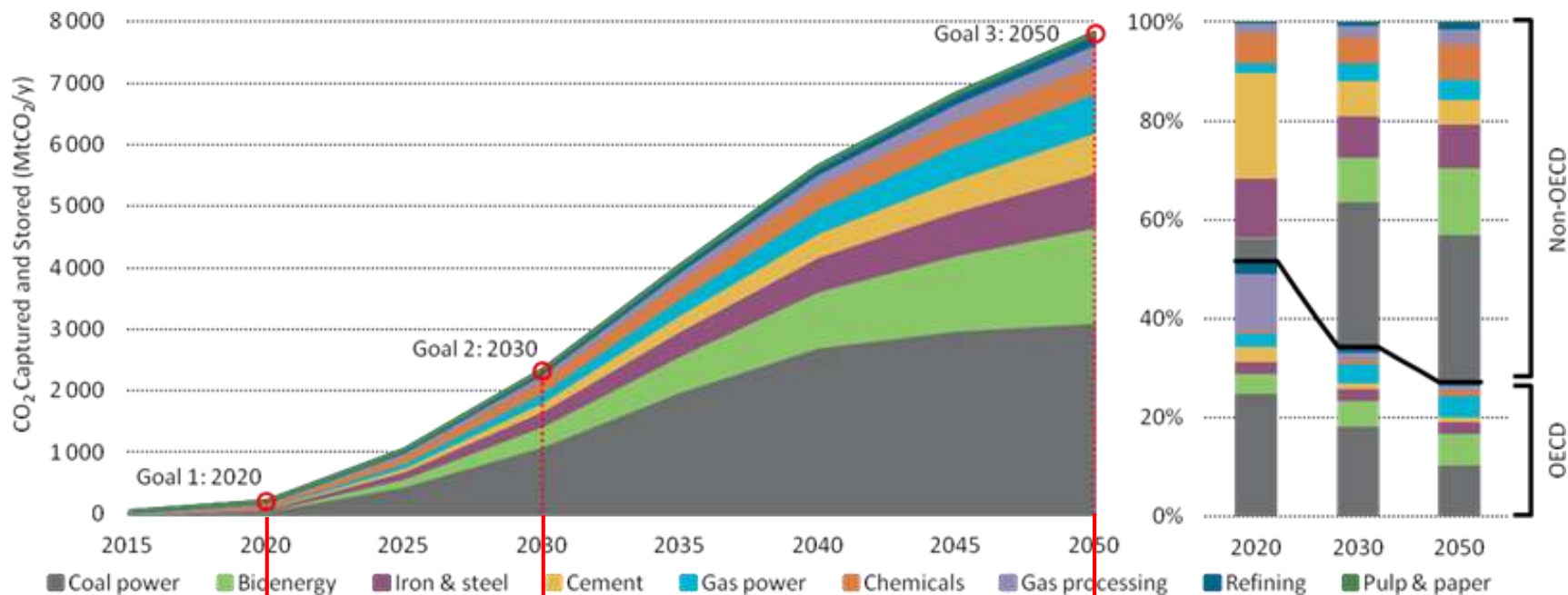
# 2013 CCS Roadmap: Key findings



- CCS is a **critical component** in a portfolio of low-carbon energy technologies, contributing 14% of the cumulative emissions reductions between 2015 and 2050 compared with business as usual.
- The individual component technologies are generally well understood. **The largest challenge is the integration** of component technologies into large-scale demonstration projects.
- Incentive frameworks are urgently needed to deliver upwards of **30 operating CCS projects by 2020**.
- CCS is not only about electricity generation: 45% of captured CO<sub>2</sub> comes from **industrial applications** between 2015 and 2050.
- The largest deployment of CCS will need to occur in **non-OECD countries, 70% by 2050**. China alone accounts for 1/3 of the global total of captured CO<sub>2</sub> between 2015 and 2050.
- The urgency of CCS deployment is only increasing. **This decade is critical** in developing favourable conditions for long-term CCS deployment.



# IEA vision: 120 Gt of CO<sub>2</sub> stored by 2050



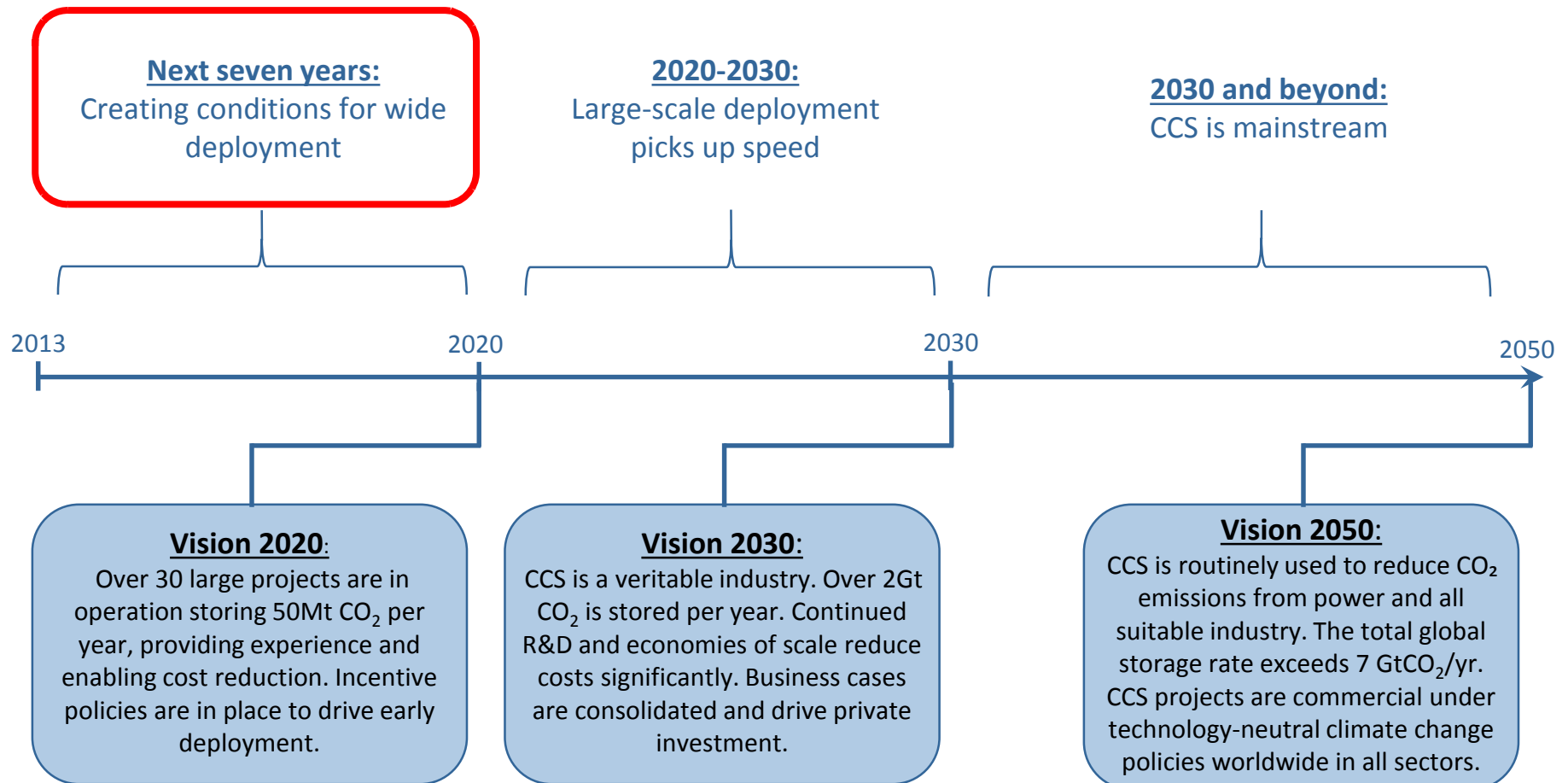
**Goal 1: 2020:**  
Over 30 large projects are in operation in power and across a range of industrial processes, storing 50Mt CO<sub>2</sub> per year.

**Goal 2: 2030:**  
Over 2Gt of CO<sub>2</sub> is stored per year. CCS is routinely used in power and certain industrial applications.

**Goal 3: 2050:**  
Over 7Gt of CO<sub>2</sub> is stored per year. CCS is routinely used in all applicable power and industry.



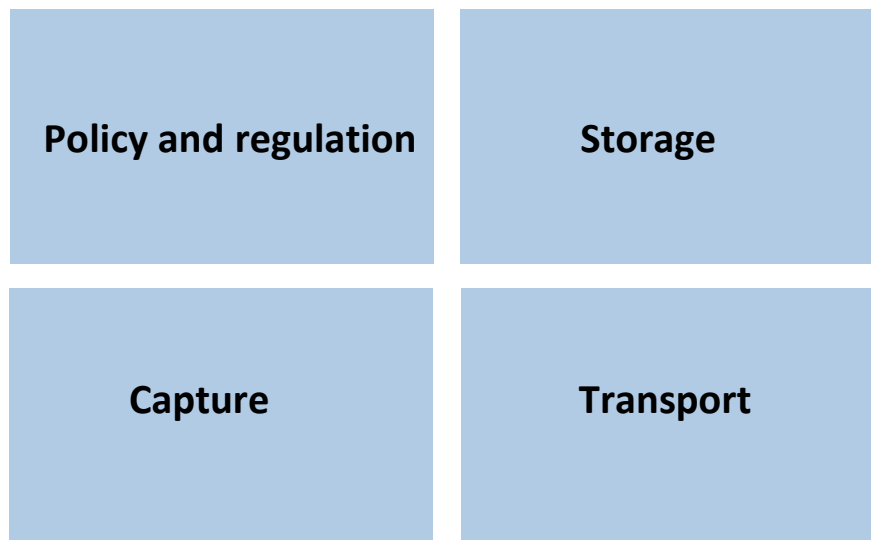
# A pathway for wide deployment of CCS



Next seven years:

# Creating conditions for wide deployment

Actions in four areas:



Vision for 2020:

**Over 30 large projects are in operation, providing experience and enabling cost reduction; incentive policies are in place to drive early deployment.**

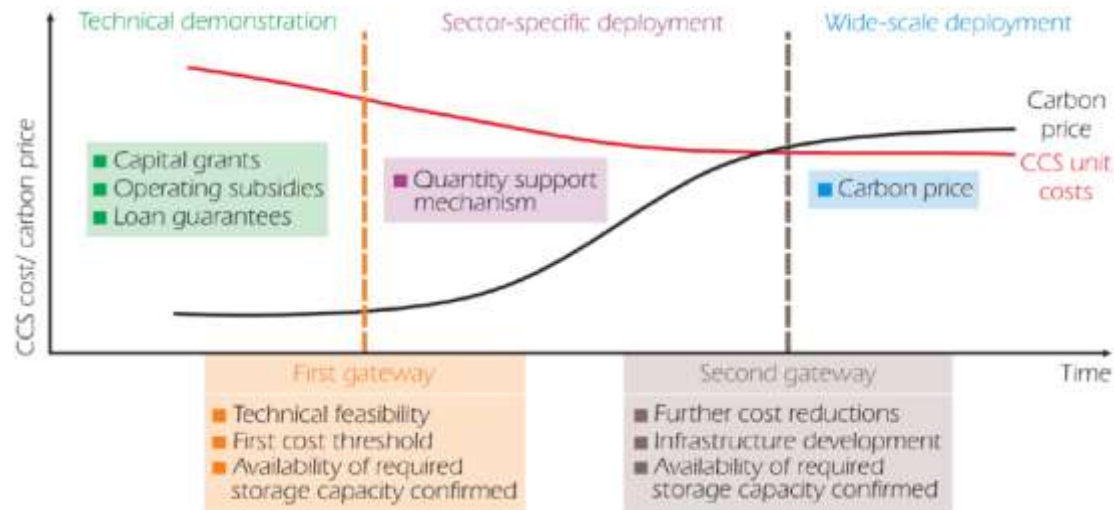


# 1. Policy and regulation conducive to integrated CCS projects

- **Action 1:** Introduce **financial support mechanisms for demonstration and early deployment** of CCS to drive private financing of projects.
- **Action 2:** Develop national laws and regulations as well as provisions for multilateral finance that effectively **require new-build power capacity to be CCS-ready**.
- **Action 3:** Significantly increase efforts to **improve understanding among the public and stakeholders** of CCS technology and the importance of its deployment.
- Action 4:** Governments and international development banks should ensure that funding mechanisms are in place to **support demonstration of CCS in non-OECD countries**.
- Action 5:** Governments should **determine their role in the design and operation of CO<sub>2</sub> transport and storage infrastructure**.

# Creating business cases for CCS

- During this decade the focus should be on **technology learning**
- The main policy mechanisms should provide mid-term **revenue certainty**
  1. Direct financial support by governments for CAPEX: grants, loans, equity etc.
  2. Direct support for operations: feed-in tariffs, production tax credits, certificates, portfolio standards etc.
  3. Leveraging existing and potential new markets for CO<sub>2</sub> (such as EOR)
  4. Specific policy to incentivise sectors in global competition (cement, steel etc.)
- Follow example of successful policies for **renewables**







## 2. Timely identification of suitable CO<sub>2</sub> storage is paramount

- **Action 6:** Implement policies that **encourage storage exploration, characterisation and development** for CCS projects.
- Action 7:** Implement **governance frameworks that ensure safe and effective storage**, encourage sound management of natural resources, and ensure that the public is appropriately consulted.
- Action 8:** Continue to develop and employ **co-ordinated international approaches and methodologies** to improve understanding of storage resources and to enhance best practice.
- Action 9:** Where CO<sub>2</sub>-EOR is being undertaken as part of geological storage operations, ensure that it is conducted under a **storage-specific regulatory regime**.
- Action 10:** **Support R&D into novel technologies that could utilise significant quantities of CO<sub>2</sub>** in a manner that leads to their permanent retention from the atmosphere.



## 3. Improvements and cost reductions on capture technology

- **Action 11:** Reduce the cost of electricity from power plants equipped with capture through continued **technology development and the use of highest possible efficiency power generation cycles.**
- **Action 12:** Prove capture systems at **pilot scale in industrial applications** where CO<sub>2</sub> capture has not yet been demonstrated.
- Action 13:** **Support research into novel capture technologies** and power generation cycles that will dramatically lower the cost of capture and resource consumption.



## 4. Development of CO<sub>2</sub> transport infrastructure to anticipate future needs

- **Action 14:** Encourage **efficient development of CO<sub>2</sub> transport infrastructure** by anticipating locations of future demand centres and future volumes of CO<sub>2</sub>.
- Action 15:** Resolve **outstanding legal issues** pertaining to the transboundary movement of CO<sub>2</sub> for geologic storage under the London Protocol.
- Action 16:** Ensure that **laws and regulations** are suitable **for pipelines and shipping**.
- Action 17:** **Reduce cost and risk of pipeline transport** by sharing knowledge gained from experience and developing common methodologies.



# Seven key actions for next seven years

<i>Lead stakeholder</i>	<i>Actions</i>
Government	Introduce financial support mechanisms for demonstration and early deployment of CCS to drive private financing of projects.
Government	Implement policies that encourage storage exploration, characterisation, and development for CCS projects.
Government	Develop national laws and regulations as well as provisions for multilateral finance that effectively require new-build, base-load, fossil-fuel power generation capacity to be CCS-ready.
Industry	Prove capture systems at pilot scale in industrial pilot applications where CO <sub>2</sub> capture has not yet been demonstrated.
Government	Significantly increase efforts to improve understanding among the public and stakeholders of CCS technology and the importance of its deployment.
Industry/R&D	Reduce the cost of electricity from power plants equipped with capture through continued technology development and use of highest possible efficiency power generation cycles.
Government	Encourage efficient development of CO <sub>2</sub> transport infrastructure by anticipating locations of future demand centres and future volumes of CO <sub>2</sub> .



# First commercial power plant with capture: Boundary Dam 3 launched on 2 October 2014



Boundary Dam 3 (Source: SaskPower)



(Source: SaskPower)

**Size:** 110 MW **Fuel:** lignite **Capture rate:** 90% of CO<sub>2</sub>, 100% of SO<sub>2</sub>  
**Capture per annum:** 1 million tonnes



# Air Products and Chemicals, Inc. ICCS Area 1

## *Steam Methane Reforming with CO<sub>2</sub> Capture*

- Port Arthur, TX (Hydrogen plant at Valero Refinery)
- 90%+ CO<sub>2</sub> capture (Vacuum Swing Adsorption) from 2 steam-methane reformers (SMRs) yielding ~925,000 tonnes CO<sub>2</sub>/year
- ~30 MWe cogeneration unit to supply makeup steam to SMRs and operate VSA and compression equipment
- CO<sub>2</sub> to Denbury “Green” pipeline for EOR in Texas at West Hastings oil field
- Total Project: \$431 MM; DOE Share: \$284 MM (66%)



### Key Dates

- Phase 2 Awarded: Jun 15, 2010
- FEED completed: Nov 2010
- Permit By Rule (PBR) and Standard Air Permits issued: May 2011
- NEPA FONSI: Jul 2011
- Construction started: Aug 2011
- Operation started: Dec 2012

### Status

- PA-1 initiated operation: Mar 3, 2013
- PA-2 initiated operation: Dec 16, 2012
- Full capacity achieved: Apr 2013
- CO<sub>2</sub> compressor trip; damage to internals; May 29, 2013; CO<sub>2</sub> compressor restart: July 1, 2013
- Has operated at >100% of design when necessary
- **1MM tonnes CO<sub>2</sub> delivered on 4/24/14**
- **1,111,076 tonnes CO<sub>2</sub> delivered as of 6/9/14**

# Lula Project, Brazil First offshore EOR Project - Petrobras



- CO<sub>2</sub> stripped from natural gas using membrane technology
- CO<sub>2</sub> reinjected with salt water for CO<sub>2</sub>-EOR
- Operational since October 2014
- Injection rate 0.7 mt/y CO<sub>2</sub>



# Four other notable projects under construction or nearing start-up

**KEMPER (US)**

3Mt pa

Source:  
**Power / IGCC**

Storage:  
**CO<sub>2</sub>-EOR**



Kemper (Source: IEA)

**GORGON (AUS)**

3,4Mt pa

Source:  
**Gas / LNG**

Storage:  
**Saline aquifer**



Gorgon (Source: Chevron)

**PARISH (US)**

1,4Mt pa

Source:  
**Power / PCC**

Storage:  
**CO<sub>2</sub>-EOR**



Parish (Source: NRG)

**QUEST (CA)**

1Mt pa

Source:  
**Oil sands / H<sub>2</sub>**

Storage:  
**Saline aquifer**



Scotford Upgrader  
(Source: Shell)



# 2015: opportunities for CCS

## Global or “near-global” processes



**United Nations**  
Framework Convention on  
Climate Change

## Industry, business, civil society



## Bilateral processes & deals



- Strengthened US-China collaboration
- Direct references to CCS
- Other bilateral processes

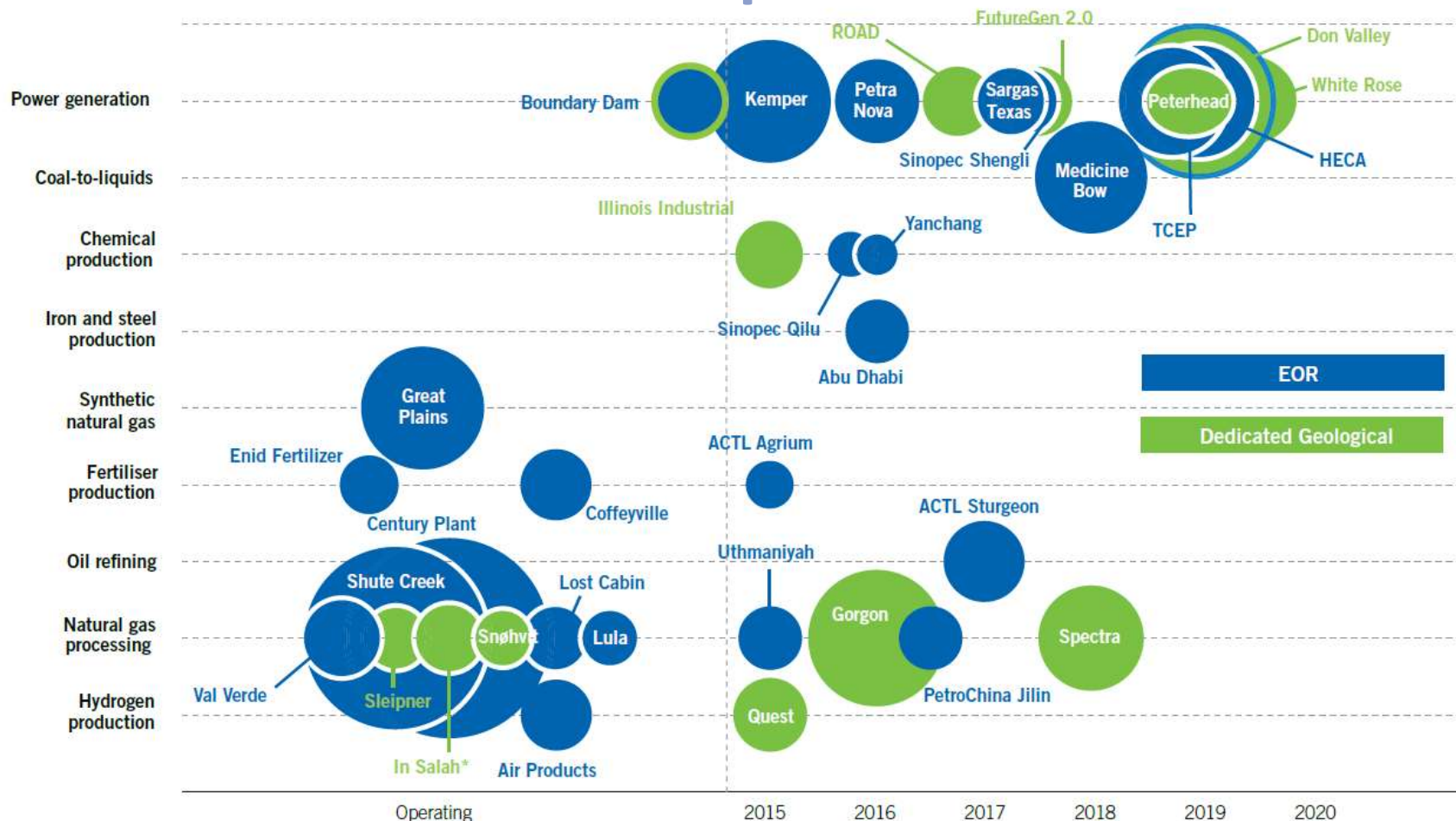
## National policy

- UK CCS programme & EMR
- USA & CA: performance standards
- Other national policy





# Around a dozen projects are at earlier stages of development



○ = 1Mtpa of CO<sub>2</sub> (area of circles proportional to capacity)

Source: GCCSI 2014

\* Injection currently suspended





# THANK YOU.

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**DOWNLOAD THE ROADMAP AT:**

<http://www.iea.org/topics/ccs/ccsroadmap2013>